EEG correlates of an induced altered state of consciousness: "mind awake/body asleep"

Justine E. Owens, PhD[1] and F. Holmes Atwater[2]

[1]*Research Director, CSCAT, McLeod Hall, School of Nursing, University of Virginia, Charlottesville, VA 22903 (U.S.A.).*

[2]*Research Director, The Monroe Institute, 62 Roberts Mountain Road Faber, VA 22938 (U.S.A.).*

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Requests for reprints:

Research Division, The Monroe Institute
62 Roberts Mountain Road, Faber, VA 22938

ABSTRACT

The goals of this study were to examine EEG patterns associated with listening to a series of low-frequency binaural beats and investigate some of the subjective experiences accompanying such stimulation. Subjects listened through stereo headphones to pure tones designed to produce binaural beats. Changes in the percentages of total EEG amplitudes were computed comparing conditions of waking rest, binaural-beat stimulus periods, and waking rest. During the stimulus periods, subjects generated significantly less alpha- and beta-frequency brain waves and significantly more delta- and theta-frequency brain waves. Participants reported that their subjective awareness was unlike that of sleep, and more akin to a trance, meditative, or prolonged hypnagogic state. This investigation suggests that low-frequency binaural beats may by associated with reduced EEG arousal and with altered states of consciousness.

Key words: Altered states of consciousness; binaural beats; frequency-following response; hypnagogia; meditative states; sleep

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INTRODUCTION

The effects of sound on human consciousness have been recognized for millennia. Sound and music were used by primitive Shamanic, Chinese, Indian, Islamic, Hebrew, Egyptian, and Greek cultures to induce altered states of consciousness in the context of religious practice and to promote healthful psychological and physical states. Throughout history, music, rhythmic drumming, and chanting have been an essential part of most cultures' rituals. Pythagoras prescribed certain sounds to clear the mind and inspire, others to soothe and relax, and still others to cure ailments of the body and spirit. Plato and Aristotle also taught that sound and music had certain curative properties and could be used as an emotional cleansing. The idea that sound and music have an influence on the character of man persisted on a large scale from Plato and Aristotle's time into the nineteenth century. A great number of classical and romantic composers saw sound and music as powerful means of influencing consciousness (Williams, 1993). Today, the idea that auditory stimulation can affect mood state and consciousness is widely accepted (Poole, 1993).

Auditory stimulation, based on a binaural-beat technology to induce altered states of consciousness is currently in widespread usage. Binaural beats are heard when pure tones (sine waves) of two different frequencies are presented, one to each ear. The brain detects phase differences between these signals that may be perceived as a pulsing beat. Under natural circumstances a detected phase difference would provide directional information. The brain processes this anomalous information differently when these phase differences are heard with stereo headphones or speakers. A perceptual integration of the two signals takes place, producing the sensation of a third "beat" frequency. The difference between the two signals waxes and wanes as the two different input frequencies mesh in and out of phase. As a result of these constantly increasing and decreasing differences, an amplitude-modulated standing wave -- the binaural beat -- is heard. The binaural beat is perceived as a fluctuating rhythm at the frequency of the difference between the two auditory inputs. It is estimated that millions of people are using technology based on binaural-beat stimulation for a variety of applications. The reported uses of the binaural-beat stimulation range from relaxation, meditation, stress reduction, pain management, improved sleep quality, and enhanced immune function, to the development of intuition, creativity, and enhanced learning.

There have been numerous anecdotal reports and several studies reporting state changes associated with binaural-beat technology. The subjective effect of listening to binaural beats has been reported as relaxing or stimulating, depending on the frequency of the binaural-beat stimulation. Binaural beats in the delta (1 to 4 Hz) and theta (4 to 8 Hz) ranges have been associated with reports of creativity (Hiew, 1995), sensory integration (Morris, 1990), relaxed or meditative states, or as an aid to falling asleep (Wilson, 1990; Rhodes, 1993). Binaural beats in the beta frequencies (typically 16 to 24 Hz) have been associated with reports of increased concentration or alertness (Monroe, 1985) and enhanced memory function (Kennerly, 1994).

The underlying mechanism of binaural-beat-induced state changes is presumed to be the "frequency-following response," although this has never been demonstrated in the range of frequencies typically used by those employing binaural beats to alter consciousness. Many studies have demonstrated the presence of an EEG frequency-following response to auditory stimuli, recorded at the vertex of the human scalp. The EEG activity was termed "frequency-following response" because its period corresponds to the frequency of the stimulus (Smith, Marsh, & Brown, 1975). The frequency-following response has been studied with 500 Hz tones (Marsh, Brown, & Smith, 1975; Yamada, Yamane, & Kodera, 1977), as a response to a missing fundamental frequency (Smith, Marsh, Greenberg, & Brown, 1978), and with rapidly repeated clicks when looking at lower frequencies (Gerken, Moushegian, Stillman, & Rupert, 1975). However, most brain-wave activity is less than 30 Hz, below the threshold of human hearing. So, in the case of tones (rather than clicks or musical tempi), binaural beats may be essential to produce a frequency-following response in the range of brain-wave frequencies. Studies suggest that the frequency-following response originates from the inferior colliculus (Smith, Marsh, & Brown, 1975). This activity is volume conducted to the cortex where it is readily recorded by scalp electrodes.

Binaural beats can readily be heard at the low frequencies that are characteristic of the EEG spectrum. This perceptual phenomenon of binaural beating suggests conditions which might facilitate changing brain waves and states of consciousness, through the frequency-following response at frequencies below 30 Hz. A frequency-following response to a binaural beat in a frequency range near to this (40 Hz) has previously been demonstrated, in the context of audiometric research (Hink, Kodera, Yamada, Kaga, & Suzuki, 1980). Evidence suggests that binaural beats are generated in the brain stem's superior olivary nucleus, the first site of contralateral integration in the auditory system (Oster, 1973). However, the way in which a frequency-following response emanating from the level of the brain stem in the ranges of the predominant EEG frequencies may influence cortical EEG and states of consciousness has not been studied.

The subjective experience of the listener may also be influenced by a number of mediating factors. For example, the willingness and skill of the listener in relaxing and focusing attention on the binaural beats may contribute to their effectiveness in inducing state changes due to the perceptual nature of binaural beats. Ultradian rhythms in the nervous system are characterized by periodic changes in arousal and states of consciousness (Rossi, 1986; Shannahoff-Khalsa, 1991; Webb & Dube, 1981). These naturally occurring shifts in arousal may underlie the anecdotal reports of fluctuations in the effectiveness of binaural beats. External factors are also thought to play roles in mediating the effects of binaural beats. For example, the perception of a binaural beat is heightened by the addition of white noise to the signal (Oster, 1973) and white noise is often used in the background of the binaural-beat stimulation. Music, relaxation exercises, guided imagery, and verbal suggestion have all been used to enhance the state-changing effects of the binaural beat.

The purpose of this study was to provide both objective and subjective descriptions of the state changes reported to accompany listening to low-frequency binaural beats. A series of mixed pure tones ranging in frequency from 50 to 1375 hertz were stereophonically presented to the subjects. This series of mixed tones (without white noise, music, or any of the other stimuli

typically employed in conjunction with binaural beats) were used to produce binaural-beat stimuli primarily in the theta and delta frequency ranges (see Figure 1). Subjects' EEGs were recorded during periods of waking rest, while listening to several binaural-beat stimuli, and again at waking rest (an A-B^N-A design), so that the changes associated with selected stimuli could be measured.
(Figure 1 here)

METHOD

Subjects

Subjects were 20 volunteers (2 women and 18 men), ranging in age from 18 to 54. Most of the subjects (75%) had some prior experience listening to binaural beats. Subjects reported normal hearing with the exception of one subject who had a bilateral hearing loss. The volume of the stimulus was raised to a comfortable level to compensate for his hearing loss so that he did not need to use his hearing aids during the experiment. None of the subjects reported a history of mental disorders.

Experimental Design

The experiment was an A-B^N-A design, with A referring to normal wakefulness with no binaural-beat stimulation and B^N referring to a series of stereophonically presented frequency mixes, with the resulting binaural-beat stimulation predominantly in the delta and theta frequency bands (1 Hz to 8 Hz). The entire experimental session lasted approximately 50 minutes, excluding preliminary instructions and electrode placement and testing.

Instructions

EEG-recording procedures were described to the subjects and any questions about the recording apparatus were answered before the experiment started. Subjects were told that EEG recordings would be made, but not when these selected recording periods would be. To control for expectation, subjects were not told what sounds they would be hearing nor what influence the sounds might have on them. Subjects were instructed to simply relax and listen to the tones.

Environment

All subjects were tested in an isolated, double-wall soundproofed, electrically-shielded booth after electrode placement and continuity testing was completed. Subjects were supine on a waterbed heated to 33^{o} C (+/-.5^{o}). Sony MDR E464 in-ear stereo headphones were supplied to each subject. A small (5 by 20 cm.) soft fabric bag filled with rice was placed over the closed eyes of the subjects to aid in the reduction of eye-movement artifact.

Procedure

There was a short (approx. 5 minute) adaptation period in the isolation booth while EEG recording equipment was adjusted, before the experimental period. After the pre-stimulus

baseline, subjects listened to the same series of thirteen frequency mixes, with the resulting binaural-beat stimulation, (BF1 - BF13) heard through their stereo headphones. Immediately after the experiment and during the removal of the electrodes, a short post-experimental interview was conducted to collect different subjective reactions. Questions about situation-related anxiety and the subjects' experiences were included. Finally, all questions raised by the subjects were answered and all subjects were asked not to discuss the experiment with other potential subjects. A questionnaire, designed to quantify the subjects' experiences during the binaural stimulation, was administered retrospectively, after completion of the study.

Materials

A questionnaire was designed to assess the subjects' subjective experiences during the binaural stimulation. The questionnaire asked subjects to describe what they experienced, specifically, their awareness of physical sensations, thoughts and feelings. Three seven point scales were used to rate the similarity of the experience to sleep, duration of conscious awareness, and degrees of drowsiness. Overall pleasantness of the experience was assessed, and adjective pairs were used to assess whether subjects were more or less "alert, groggy, focused, energetic, refreshed, and disoriented."

EEG Recording

Subjects were connected to a 24-channel digitizing EEG computer (NRS-24, LEXICOR Medical Technology Inc., Boulder, Colorado) using V151 software. The entire standard 10/20 International System montage of electrodes was used (Electro-Cap™). The reference was linked-ears balanced for impedance by metered calibration to less that 1k ohm difference. The electrode at the midline vertex served as ground. The nineteen active EEG channels and reference electrode placements were tested to ensure contact resistance of 10K ohms or less and balanced closely for impedance level. Electro-Gel™ was used in the prescribed manner to provide for adequate electrical conductivity. All EEG data were recorded and saved on an IBM compatible 386-AT computer in raw form.

The NRS-24's sampling rate of 256 samples per second was used with the high pass filter set to off. The NRS-24 provided for an EEG frequency response of 1-64 Hz (less 60 Hz, due to a notch filter), a frequency resolution of 1 Hz, and a temporal resolution of one second. Note that this temporal resolution is pertinent to the length of the EEG recording periods. Each epoch was one second long, creating an integer array of 256 points per channel per epoch. Ninety epochs of EEG data were recorded for each period.

The NRS-24 was calibrated for frequency response of each channel at each sampling rate using a swept frequency approach, according to the procedures outlined in the NRS-24 software manual. The purpose of this calibration was to compensate for the roll-off of the anti-aliasing analog filters. Frequency response corrections were applied to ensure flat spectrums across the frequencies of interest. The NRS-24 was also normalized for amplitude response at 10 Hz at each channel for every combination of sampling rate and gain setting. This procedure compensated for any differences in amplification across all channels for each sampling rate and gain setting. Normalization was used in conjunction with frequency-response calibration to

ensure similar spectral amplitudes across channels. Both calibration and normalization verifications were periodically conducted thereafter. All parameters remained stable throughout the time of the testing and no adjustments were ever needed to recalibrate or renormalize.

After an eyes-closed baseline EEG recording of 90 seconds (Period 1), subjects were given approximately one minute to make any final adjustments to their body position to ensure their comfort before beginning the binaural-beat stimulation. EEG recordings were then made during six 90 second intervals (Periods 2 through 7). After the completion of the binaural-beat stimulation, subjects were given approximately one minute to compose themselves. A post-stimulus EEG recording (Period 8) was then made. All EEG recording periods were ninety seconds. An outline of the approximately fifty-minute procedure is provided in Figure 2. (Figure 2 here)

Preliminary EEG signal analyses consisted of 1) the analog-to-digital conversion of the raw brain waves by the NRS-24 unit; 2) editing the digitized EEG; 3) performing Fast-Fourier Transform (FFT) of the data. EEG editing was based on artifact rejection. The rejected epochs were those containing obvious eye-movement artifact and were selected by using the V151 software artifact utility set to a threshold of 50 microvolts. When EEG exceeded 50 microvolts at electrode sites FP1 or FP2, visual inspection of the wave form was used to distinguish artifact from normal brain-wave activity. The numbers of selected artifact epochs were entered into a computer file for rejection prior to performing the FFT spectral computations.

FFT spectral computations were done with the V151 software provided with the NRS-24 and then exported to ASCII files. Results of this computation yielded amplitude values (microvolts peak-to-peak) for eight bands of data -- Delta (0.8 Hz to 4 Hz), Theta (4 Hz to 8 Hz), Low Alpha (8 Hz to 10 Hz), High Alpha (10 Hz to 13 Hz), Beta (13 Hz to 32 Hz), Low Gamma (32 Hz to 52 Hz), High Gamma (52 Hz to 64 Hz), and SMR (Sensori-Motor Rhythm) or spindles (12 Hz to 15 Hz). Each subject's exported file contained ninety epochs of nineteen channels of FFT spectral data (including mean and standard deviation values) for each of the subject's eight EEG recording periods. Vertex delta and occipital alpha were chosen due to the conventional use of sites for recording delta and alpha EEG.

EEG Analysis

Using average FFT values for each 90 second recording period, EEG amplitude was computed in alpha (O1), spindle (CZ), beta (T3), theta (CZ), and delta (CZ) bands. Average amplitudes for each stimulus period (Periods 2 - 7) were divided by the average amplitudes for the pre-stimulus and post-stimulus baseline periods (Periods 1 and 8) with the following formula, (stimulus amplitude/baseline amplitude) - 1, so that departures from 0 (zero) indicate change. Positive scores indicate an increase in amplitude for the stimulus period, relative to baseline. Similarly, negative scores indicate a decrease in amplitude relative to baseline. Amplitude comparisons between each of the stimulus periods and both the pre-stimulus baseline and post-stimulus baseline were made with matched pairs t tests, evaluating the differences between the changes in amplitude from 0 (zero).

RESULTS

The changes in delta, theta, low alpha, high alpha, spindle, and beta frequencies, for each of the stimulus periods compared to both pre-and post-stimulus baselines, are presented in Table 1 and in Figure 3 and Figure 4.

Delta and theta amplitudes increased over the course of the stimulus periods, when compared to the pre-stimulus and the post-stimulus baseline recordings. Changes in the delta band ranged from 6% to 36% increases in amplitude compared with the pre-stimulus baseline ($t = 1.96$, $p < .07$ to $t = 3.02$, $p < .007$), and 20% to 51% increases in delta amplitude compared with the post-stimulus period ($t = 3.7$, $p < .002$ to $t = 3.93$ $p < .0009$). Changes in the theta band ranged from 4% to 19% increases in amplitude compared with the pre-stimulus baseline ($t = .92$, $p < .37$ to $t = 2.99$, $p < .007$) and 16% to 30% increases in amplitudes compared with the post-stimulus period ($t = 2.8$, $p < .01$ to $t = 4.98$, $p < .0001$).

In contrast, both low and high alpha amplitudes and beta amplitudes decreased during the stimulus periods when compared to the pre-stimulus and the post-stimulus baseline recordings. The changes in the high-alpha band ranged from 13% to 25% decreases in amplitude compared with the pre-stimulus period ($t = -2.58$, $p < .02$ to $t = -5.8$, $p < .0001$) and 13% to 28% decreases in amplitude compared with the post-stimulus period ($t = -1.7$, $p < .1$ to $t = -5.5$, $p < .0001$). The changes in the low-alpha band ranged from 30% to 43% decreases in amplitude compared with the pre-stimulus period ($t = -2.77$, $p < .01$ to $t = -7.5$, $p < .0001$) and 33% to 42% decreases in amplitude compared with the post-stimulus period ($t = -3.5$, $p < .002$ to $t = -6.0$, $p < .0001$).

The changes in the beta band ranged from 14% to 19% decreases in amplitude compared with the pre-stimulus period ($t = -2.1$, $p < .04$ to $t = -3.6$, $p < .002$) and 10% to 18% decreases in amplitude compared with the post-stimulus period ($t = -1.4$, $p < .2$ to $t = -3.1$, $p < .007$).

The amplitude of the SMR or spindle band (12-15 Hz) decreased 13% during the first stimulus and then the changes decreased progressively over the course of the stimulus series with no difference in spindle amplitude by the last stimulus period. A similar pattern was seen in spindle amplitudes when the stimulus epochs were compared with post-baseline, with the observed changes tapering off somewhat more gradually.
(Table 1 here)
(Figures 3 & 4 here)

Individual Differences in EEG Amplitude Changes

Individual subject's EEG changes are shown in Figures 5, 6, 7, 8. These figures show amplitude variations (in microvolts) during baseline, stimulus periods and post-baseline. These graphs show that while the EEG changes generally increased during the course of the stimulus sequence, EEG changes waxed and waned in some subjects (see for example, Figure 6 Subject B).

Reports of Subjective Experience During the Stimulus Periods

When asked to compare their experience with normal sleep the majority (80%) of the subjects felt that their experience was either very different from sleep or more different than similar. The majority (80%) of the subjects also reported being conscious and aware most of the time or all of the time during the experiment. 90% of the subjects rated their degree of awareness during the experiment as either more aware than drowsy or very aware. All subjects reported feeling more alert, more energetic, and more refreshed as compared to before the experiment. A summary of the questionnaire responses is presented in Table 2.
(Table 2 here)

DISCUSSION

The results indicate that EEG activity during the stimulus periods can be distinguished from the baseline EEG recordings, both with increased theta and delta activity and decreased alpha and beta activity. Decreases in alpha and beta amplitudes coupled with increases in theta and delta activity are indicative of reduced cortical arousal (Berger et al, 1968). The increased changes over the course of the stimulation, most striking in the delta band, are suggestive of a deepening trend -- the process of progressive relaxation and falling asleep. However, sleep is associated with a loss of consciousness and 80% subjects reported maintaining consciousness all or most of the time, and 70% said that the experience was extremely or very different from sleep.

Some altered states of consciousness are also associated with reduced levels of arousal (Empson, 1986) and a suppression of occipital alpha. An essential difference between these altered states of consciousness and sleep is, of course, conscious awareness. The way in which to characterize states that have some physiological resemblance to sleep states, but which are subjectively experienced as distinctive states of awareness, has been a source of some debate. There is a growing body of evidence which suggests, however, that reduced cortical arousal while maintaining conscious awareness is possible, (Fischer, 1971; West, 1980; Delmonte, 1984; Goleman, 1988; Jevning, Wallace, & Beidebach, 1992; Wallace, 1986; Mavromatis, 1991) with these states variously referred to as meditative, trance, altered, hypnagogic, hypnotic, and twilight learning states (Budzynski, 1986). Broadly defined, the various forms of altered states rest on the maintenance of conscious awareness in a physiologically reduced state of arousal marked by parasympathetic dominance (Mavromatis, 1991). Recent physiological studies of highly hypnotizable subjects and adept meditators indicate that maintaining awareness with reduced cortical arousal is indeed possible in selected individuals with this natural ability or acquired skill (Sabourin, Cutcomb, Crawford, & Pribram, 1990; Crawford, Brown, & Moon, 1993).

In contrast to the other EEG bands, changes in spindle activity decreased over the course of the stimulation. By the end of the stimulus sequence, spindle activity was equivalent to baseline activity, in comparison to the increases in delta and theta activity which were highest at that point. That EEG spindle activity was equivalent to baseline during significantly increased levels of theta and delta may be a distinguishing feature of the altered states achieved during this study, in contrast to the normal process of falling asleep. However, plots of the individual subjects EEG changes suggest that peaks in delta activity are sometimes accompanied by peaks in spindle activity (see Subject B in Figure 6). Further studies comparing EEG spindles during

sleep and altered states of consciousness may shed further light on the potential of spindle activity in distinguishing states of consciousness.

The phrase "mind awake/body asleep" conveys the subjective experience of dissociation from kinesthetic and other physical senses, while maintaining awareness or consciousness (Monroe, 1985). The phrase points to the similarities and differences between this state and sleep. As previously noted, the conventional definition of sleep included the presence of "unconsciousness" and, historically, this feature of sleep was generally unquestioned. However, research has shown that conscious experience and volitional behavior is indeed possible in physiologically "asleep" subjects (LaBerge, Nagel, Taylor, Dement, & Zarcone, Jr. 1981; LaBerge, Levitan, & Dement, 1986). The longstanding association between sleep and unconsciousness creates semantic difficulties in describing states such as lucid dreams, which typically occur during REM sleep, and the states experienced by subjects in this study which appear more akin to the early stages of NREM sleep and hypnagogia (Mavromatis, 1991). Again, an obvious difference between sleep and the "mind awake/body asleep" state is awareness or consciousness. The growing acceptance of "consciousness" as a legitimate concept in the study of cognition and the brain, makes this distinction more useful than it may have been in the past.

During the post-experimental interviews consciousness was reported to be maintained, by most subjects, throughout the experiment. The contents of consciousness varied, with the focus of attention shifting from the external environment to internal mentation and occasional awareness of the physical body, but more typically reported was a sense of dissociation from the physical body, with maintained awareness. Others described elation experiences during which they felt connected in some way to a universal mind or oneness. So, an important difference between the experience of participating in the experiment and the experience of falling asleep was the richness of the mental experience typically reported. Others have reported similarly rich mental experiences during partial sleep states (Gabbard & Twemlow, 1984). These kinds of experiences have been described as "loosening of ego boundaries" and typified by openness, sensitivity, empathy, and diffuse-absorbed attention. This richness points to the difficulty in describing the experience in a unitary way, which in itself distinguishes the states reported from the typical experience of falling asleep. It has been suggested that many, even most of the varied altered states are partial or dissociated sleep states (Broughton, 1986). Altered states are often described as "boundary" states, bordering on the brink between consciousness and unconsciousness, with a paradoxically rapt attention, which sometimes fades into the unconscious state (Mavromatis, 1991).

As mentioned in the Introduction, one application of binaural beats is as an aid to falling asleep. Some subjects in this study reported lapses of consciousness during portions of the experiment and this points to the transitional nature of the "mind awake/body asleep" state and sleep. As both states involve reduced cortical arousal (decreased alpha and increased delta activity), passing readily from one state to the other would be expected, and this has often been reported by persons using binaural-beat technology. Some who wish to experience altered states of consciousness simply fall asleep in this pursuit. If they are, however, able to avoid falling asleep (becoming unconscious) it is common to experience hearing one's self snore and to be able to speak without altering sustained EEG patterns. (Banquet, 1973). It may be that the

richness of the psychological experiences often reported emerges from maintaining awareness beyond the transitory shift from waking to sleep; extending the borderline to an experience in itself.

Like sleep, the altered states experienced in the study appear to be restorative, healthful states and subjects reported feeling more alert, energetic and refreshed compared to before the binaural stimulation. This subjective report is in line with the EEG comparisons to post-baseline, which showed greater changes in the delta and theta bands, suggesting that subjects were more aroused or alert in the post-stimulus period compared with the pre-stimulus baseline.

A basic question that is raised by this study is the role of binaural beat-stimulation in directly causing, or more indirectly promoting, the state changes observed. The subjects, for the most part, had considerable previous experience in using binaural-beat stimulation as aid to inducing altered states of consciousness. It may be that the subjects in this study are naturally adept at changing states of consciousness, or that they have acquired this ability through repeated practice with binaural-beat stimulation. The practice of meditation is associated with increasing adeptness over time and the power of binaural beats to induce altered states reportedly increases with practice. In addition, belief in the potency of binaural beats to engender altered states may also contribute significantly to their effectiveness.

It is a widespread practice in techniques of inducing altered states of consciousness, to focus attention on repetitive mental contents. For example, repeating a mantra or rhythmic drumming are techniques often used to induce altered states. The binaural beat may serve as a focal point of attention in much the same way. However, it may be that repetitive stimuli -- whether they be mantras, lullabies, ritual drums, or binaural beats -- may achieve their effects through a frequency following response, and so this "explanation" for the state changes associated with binaural beats may be complementary rather than competing. Similarly, positive beliefs may serve to enhance attention to binaural beats and so amplify the perception of them and their effects.

The apparent trend toward a deepening state change over time suggests the importance of taking into consideration naturally occurring, progressive state changes associated with falling asleep. Repeating stimuli and low frequency rhythms, such as those used in lullabies, are used to promote sleep as well as to induce states of relaxation and meditation. One way to characterize the state changes experienced in this study is maintaining the middle ground between sleep and wakefulness and it may be that adept meditators are capable of extending the duration of this state of awareness, past the point where consciousness is typically lost. Again, further elucidation of the relationship of altered states and typical sleep may shed further light on the role of the sleep process in causing the physiological changes associated with binaural-beat stimulation.

The possibility remains that the binaural beat has a direct physical effect on the EEG causing a physiological state change through a frequency-following response. It should be emphasized however, that a possible direct effect does not rule out the interaction of binaural-beat stimulation with the basic rest-activity cycle or with "higher order" memory or attentional processes. On the contrary, the use of the binaural beats as an aid to falling asleep, and the

learning process associated with binaural-beat listening, point to the relevance of these factors in understanding the role of binaural beats and consciousness. It seems likely that natural state changing mechanisms (Steriade, McCormick, & Sejnowski, 1993), individual differences, prior binaural beat experience, and beliefs all may contribute to the effects of binaural beat stimulation.

In sum, the EEG changes observed in this study and the widespread use of binaural-beat stimulation to achieve psycho-physiological state changes, suggest that the further studies of binaural-beat stimulation are worthwhile. We are currently investigating the mechanism of these changes, looking more closely at individual differences and the frequency-following response to binaural beat stimulation, to further the understanding of the EEG changes associated with binaural-beats. This work-in-progress will complement clinical studies evaluating the efficacy of binaural-beat stimulation across the wide range of purposes for which they are being used. Hopefully, these efforts will contribute to a greater knowledge of the widely used and under-investigated use of auditory stimulation as a "Mind/Body" therapy and the psychophysiology of altered states of consciousness.

In order to acquire continuity of consciousness, unaffected by lapses into unconscious states, you must hold yourself at the junction of all the states, which constitutes the links between sleeping, dreaming, and waking: the halfsleep or Fourth State.

FROM A TENTH-CENTURY TANTRIC TEXT (Mavromatis, 1991)

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